Claims

[c1] A method for imaging a description of a zone behind a casing of a well, the method using a logging tool positionable inside the casing, the logging tool carrying a plurality of acoustic transducers, the method comprising:

insonifying (72) the casing with a first acoustic wave using a first acoustic transducer for transmitting among the plurality of acoustic transducers, the first acoustic wave having a first mode that may be any mode of a set of modes defined as follows: extensional mode, thickness mode, flexural mode;

selecting (71) at least a first acoustic transducer for receiving among the plurality of transducers, the first acoustic transducer for receiving having a location adapted to receive a first echo corresponding to the first acoustic wave;

receiving (73) at the first acoustic transducer for receiving the first echo, and producing a first signal;

extracting (76) from the first signal a first measurement;

insonifying (74) the casing with a second acoustic wave using a second transducer for transmitting among the plurality of acoustic transducers, the second acoustic wave having a second mode that may be any mode of the set of modes and is distinct from the first mode;

selecting (79) at least a second acoustic transducer for receiving among the plurality of transducers, the second acoustic transducer for receiving having a location adapted to receive a second echo corresponding to the second acoustic wave;

receiving (75) at the second acoustic transducer for receiving the second echo and producing a second signal;

extracting (77) from the second signal a second measurement;

evaluating (78) from a combination of the first measurement and the second measurement the description of the zone behind the casing of the well.

[c2] The method according to claim 1, wherein the description of the zone behind the casing (92) is characterized by a quality of a fill-material disposed in an annulus (95) between the casing (92) and a formation.

[c3] The method according to any one of claims 1 to 2,
wherein the first mode is a flexural mode;
wherein the second mode is a thickness mode;

[c4] The method according to claim 3 wherein:
the first measurement is a measurement of a propagation time;
the second measurement is a measurement of an amplitude decay rate with time.

[c5] The method according to claim 4 further comprising:
calculating a value of an impedance of a matter within the annulus and a value of a velocity of a compressional wave within the annulus from the measurement of the propagation time and the measurement of the amplitude decay rate;
evaluating a value of a density of the matter within the annulus from the calculated value of the acoustic impedance and the calculated value of the compressional wave velocity.

[c6] The method according to claim 4, further comprising:
selecting among the plurality of acoustic transducers an additional acoustic transducer for receiving (96b), the additional acoustic transducer for receiving (96b) being distinct from the first acoustic transducer for receiving (96a), the additional acoustic transducer for receiving (96b) having a location adapted to receive an additional echo corresponding to the first acoustic wave;

receiving at the additional acoustic transducer for receiving **(96b)** the additional echo and producing an additional signal;

extracting a measurement of a first amplitude from the first signal and a measurement of an additional amplitude from the additional signal.

[c7] The method according to any one of claims 4 or 6, further comprising:

calculating a plurality of observed parameters at least from the measurement of the propagation time and the measurement of the amplitude decay rate.

defining a set of quality events of a matter within the annulus;

calculating for each quality event an a posteriori probability of the quality event for the calculated values of the observed parameters ;

selecting a most probable quality event;

[c8] The method according to claim 7, further comprising:

estimating at least one quality parameter from the selected quality event and from the calculated values of the observed parameters.

[c9] The method according to claim 8, wherein:

the plurality of observed parameters comprises an impedance of the matter within the annulus **(15, 38, 410, 95, 106)** and a flexural wave attenuation of the first acoustic wave **(A)** along the casing **(14, 24, 32, 44, 92, 103)**;

a plurality of quality parameters is estimated, the plurality of quality parameters comprising a density of the matter within the annulus **(15, 38, 410, 95, 106)**, a shear wave velocity of the first acoustic wave through the matter and a compressional wave velocity of the first acoustic wave through the matter.

[c10] The method according to any one of claims 1 to 2,

wherein the first mode is a flexural mode;

wherein the second mode is an extensional mode;

[c11] The method according to any one of claims 1 to 10, further comprising:

insonifying the casing with a third acoustic wave using a third acoustic transducer for transmitting among the plurality of acoustic transducers, the third acoustic wave having a third mode, the third mode being distinct from the first mode and the second mode;

selecting a third acoustic transducer for receiving, the first transducer for receiving having a location adapted to receive a third echo corresponding to the third acoustic wave;

receiving at the third acoustic transducer the third echo and producing a third signal;

extracting from the third signal a third measurement;

evaluating from a combination of the first measurement, the second measurement and the third measurement the description of the zone behind the casing of the well.

[c12] The method according to any one of claims 1 to 11, wherein:

the fill-material is cement.

[c13] The method according to any one of claims 1 to 12, further comprising:

guiding and rotating the logging tool inside the casing in order to evaluate the description of the zone behind the casing within a range of depths and azimuthal angles.

[c14] A system for imaging a description of a zone behind a casing (**92**) of a well, the system comprising:

a logging tool (**97**) positionable inside the casing (**92**) and carrying a plurality of acoustic transducers;

a first acoustic transducer for transmitting (**93**) among the plurality of acoustic transducers to insonify the casing (**92**) with a first acoustic wave having a

first mode that may be any mode of a set of modes defined as follow: extensional mode, thickness mode, flexural mode;

a second acoustic transducer for transmitting (**94**) among the plurality of acoustic transducers to insonify the casing (**92**) with a second acoustic wave having a second mode that may be any mode of the set of modes and is distinct from the first mode.

at least a first acoustic transducer for receiving (**96a**) having a location adapted to receive a first echo corresponding to the first acoustic wave, to produce a first signal;

at least a second acoustic transducer for receiving (**94**) having a location adapted to receive a second echo corresponding to the second acoustic wave, to produce a second signal;

extracting means to extract a first measurement and a second measurement respectively from the first signal and the second signal; and

processing means to evaluate a quality of the description of the zone behind the casing (**92**) from a combination of the first measurement and the second measurement.

[c15] The system according to claim 14, wherein the description of the zone behind the casing (**62**) is characterized by a quality of a fill-material disposed in an annulus (**95**) between the casing (**62**) and a formation.

[c16] The system according to any one of claims 14 or 15, wherein the first acoustic transducer for transmitting (**93**) and the first acoustic transducer for receiving (**96a**) are aligned at an angle larger than a shear wave critical angle of an interface (**91**) between the casing (**92**) and a fluid within the casing (**92**), the angle being measured with respect to a normal to the local interior wall of the casing (**92**).

[c17] The system according to any one of claims 14 to 16, wherein

the second acoustic transducer for transmitting (**94**) is directed to the normal to the local interior wall of the casing (**92**);

the second acoustic transducer for transmitting (**94**) has a frequency spectrum selected to stimulate a selected radial segment of the casing (**92**) into a thickness resonance.

[c18] The system according to any one of claims 14 to 17, further comprising:

an additional acoustic transducer for receiving (**96b**) among the plurality of acoustic transducers, the additional acoustic transducer for receiving (**96b**) having a location adapted to receive an additional acoustic wave corresponding to the first acoustic wave, the additional acoustic transducer for receiving (**96b**) being distinct from the first acoustic transducer for receiving (**96a**), to produce an additional signal;

[c19] The system according to any one of claims 14 to 18, further comprising:

an array (**101**) of transducers elements located on a periphery of the logging tool, to insonify the casing (**103**) at least with the first acoustic wave and the second acoustic wave propagating within the casing (**103**) with respectively the first mode and the second mode.

[c20] The system according to any one of claims 14 to 19, wherein:

the fill-material is cement.